DEEP PLOWING OF SANDY SOIL

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DEEP PLOWING OF SANDY SOIL

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Since about 1945 farmers in Oklahoma and Texas have been deep plowing to improve some types of sandy soil. Agricultural Conservation Program (ACP) payments were made for deep plowing 241,301 acres of sandy soil in Oklahoma and 2,299,184 acres in Texas during 1950–59. Usually increases in crop yields resulting from deep plowing paid for the cost of plowing in 1 or 2 years.

In Kansas, deep plowing was started in 1953 with the help of ACP payments. Its use by farmers rapidly increased through 1956, but deep plowing was virtually stopped when payments were discontinued in 1957. During that period 12,304 acres were deep plowed.

The primary purpose of deep plowing is to bring adequate amounts of clod-forming subsoil to the surface (fig. 1), and thereby to reduce

Figure 1.—This disk plow on sandy soil can reach a depth of 2 feet to bring loamy subsoil to the surface. Each disk will cut a furrow about 17 inches wide.

wind erosion. Although many times wind erosion has not been controlled after deep plowing, yield increases have been obtained for a

limited number of years. The conditions required for deep plowing must be carefully met if greatest benefits are to be received.

Plowing is usually from 20 to 24 inches deep. However, the required depth of plowing varies with the depth to the finer textured subsoil. Enough of the subsoil must be brought to the surface to reduce wind erosion.

To qualify for ACP cost sharing, the usual requirements are as follows:

1. The minimum depth of plowing on sandy soil with a subsoil containing 20 percent or more of clay should be the depth necessary to extend at least 1 inch into the subsoil for each 2 inches of depth of sandy soil. If the subsoil contains 40 percent or more of clay, deep plowing may be detrimental, because too much clay may slow up the absorption of rainfall and thereby increase runoff.
2. Plowing should be done in a solid block and not in a strip pattern.
3. Small areas with subsoil containing less than 20 percent of clay should not exceed 10 percent of the area to be plowed.
4. The plow should turn the soil completely over. To avoid mixing the surface soil with subsoil, the diameter of the disk, if the disk plow is used, must be at least twice the required depth of plowing.

Little information has been available on how effective deep plowing is in controlling wind erosion and how long its benefits last. Consequently, investigations were undertaken on this problem in Oklahoma in 1947, in Texas in 1950, and in Kansas in 1954. The results so far obtained in Oklahoma have been reported by Cunningham (*9*)[1] and Harper and Brensing (*11*). These authors strongly recommend deep plowing of some types of sandy soil. They contend that a surface soil with a clay content of 8 percent or more is sufficiently resistant to wind erosion. Results obtained by Chepil (*5*) and Chepil and Woodruff (*8*) do not support this contention. The investigations reported here for Texas are completed, but those for Kansas are continuing.

PROCEDURES

Texas

In 1950, two 4-acre plots, each 175 by 1,000 feet, on the Terry County Experiment Station, Brownfield, Tex., were plowed, one 14 inches and the other 17 inches deep. These plots were on Amarillo loamy fine sand and were planted principally to cotton and sorghum. They were sampled just before, just after, and 5 years after plowing. Six composite soil samples were taken from each of four different depths, which were sometimes below the depth of plowing.

The soil samples were analyzed for sand, silt, clay, organic matter, total nitrogen, phosphorus (as P_2O_5), potassium (as K_2O), calcium (as CaO), pH, and soil cloddiness. Potential annual soil loss by wind was estimated from soil cloddiness.

Kansas

In 1954, 18 deep-plowed and 14 nonplowed fields scattered throughout southwestern Kansas were chosen for this study. Each non-

[1] Italic numbers in parentheses refer to Literature Cited, p. 14.

plowed field was adjacent to one or two deep-plowed fields. Ten additional fields—five plowed and five adjacent nonplowed—were chosen in 1956. All were at least 40 acres each, and they were planted almost continually to sorghum. They were predominantly on Richfield and Dalhart fine sandy loam and loamy fine sand; a few had small areas of Vona and Tivoli fine sand. Most of them were disk plowed to a depth of 20 to 22 inches.

By 1956, some of the original nonplowed fields had been plowed so that there were 29 plowed and 13 nonplowed fields.

Composite soil samples were taken from each field in August or September during 1954 through 1960, except for 1959, to determine differences in soil characteristics between plowed and nonplowed fields and changes in these characteristics with years after plowing. Six composite soil samples from each of 26 fields plowed before 1957 and from each of 6 nonplowed fields were taken down to 4 inches. Each sample was from representative areas about 20 feet in diameter. Composite soil samples from five additional plowed fields and five nonplowed fields were taken from various depths to 20 inches, the depth of plowing.

The soil samples were analyzed for degree of cloddiness and mechanical stability of clods by the rotary-sieve method of Chepil (*4*), potential annual soil loss by wind by the method of Chepil and Woodruff (*7*, *8*), water-stable soil-particle distribution by the modified wet-sieving method of Yoder (*13*), sand, silt, and clay contents by the modified method of Bouyoucos (*1*), organic matter by the wet-combustion method of Walkley (*12*), available phosphorus (P_2O_5) by method 1 of Bray and Kurtz (*2*), and pH by the standard method of the Association of Official Agricultural Chemists.

RESULTS

Texas

Plowing of two plots of Amarillo loamy fine sand in Texas, one to a depth of 14 and the other to 17 inches, decreased the sand in the top 3 inches on an average from 92 to 78 percent and increased the clay from about 4 to 14 percent, as shown in figure 2. It changed the texture of the surface soil from a loamy sand to a sandy loam. However, 5 years after plowing, the sand was increased and the clay was decreased to almost the same levels as before plowing. Severe wind erosion during that period apparently removed more than half of the clay from the surface soil or buried the clayey material and left at least 18 inches of sand on top. Silt content before and after plowing can be readily determined by adding the percentage of clay and sand and subtracting the total from 100 (fig. 2). Removal of silt is less important than removal of clay or accumulation of sand.

Deep plowing increased the organic matter of the surface soil on an average from 0.35 to 0.55 percent. Five years after plowing, the organic matter was reduced from 0.55 to 0.45 percent.

Deep plowing almost doubled the total nitrogen in the surface soil, but 5 years later the nitrogen diminished to less than half of that present just before plowing.

Deep plowing substantially increased the potassium (K_2O) and

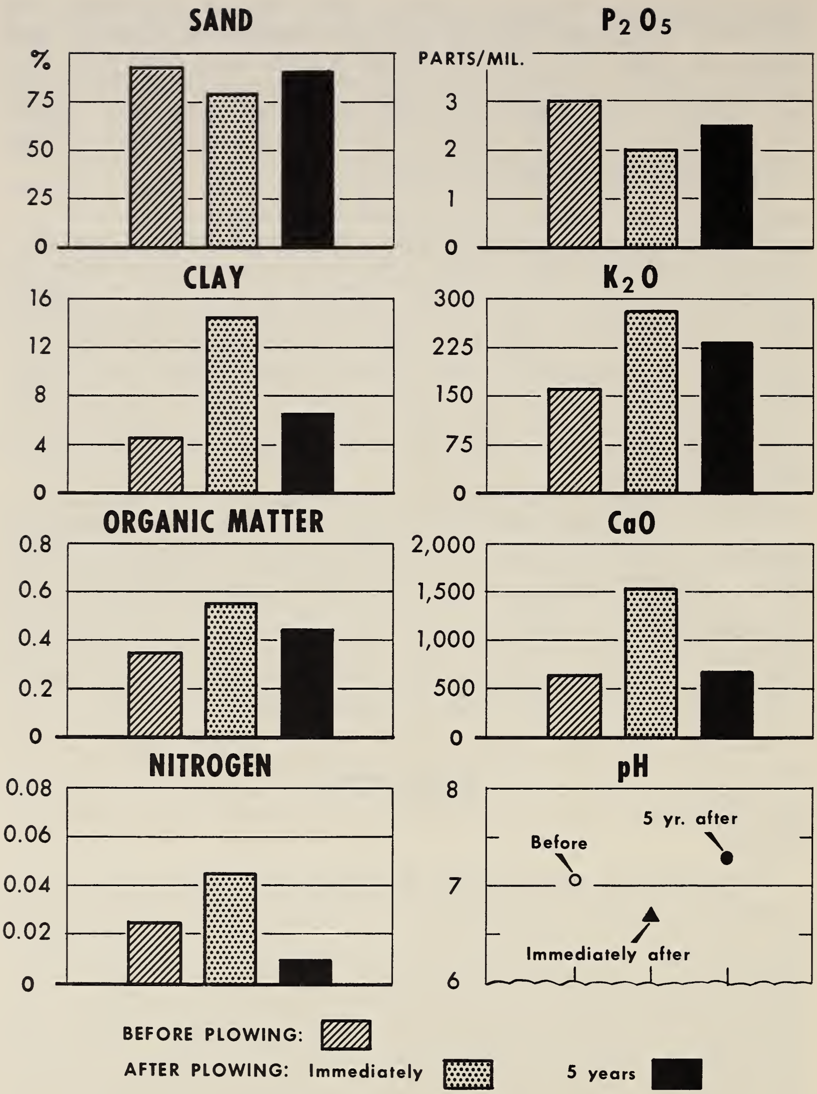

FIGURE 2.—Soil conditions in top 3 inches just before, just after, and 5 years after deep plowing on Amarillo loamy fine sand in Brownfield, Tex. Plowing averaged 15½ inches deep.

calcium (CaO) of the surface soil. Five years later these constituents were back to about what they were before plowing.

The average soil conditions at various depths just before, just after, and 5 years after deep plowing on Amarillo loamy fine sand are shown in figure 3. The clay content before plowing was about 5 percent at

the surface and graded to 18 percent at plow depth. Immediately after plowing, the clay content was slightly less than 15 percent all through the plowed layer, which was 14 to 17 inches deep. This result indicates that plowing mixed the soil considerably. Five years after plowing, the clay content was reduced drastically. Apparently wind erosion removed and deposited the soil material, sorted out and removed or diluted much of the clay, and accumulated some sand from

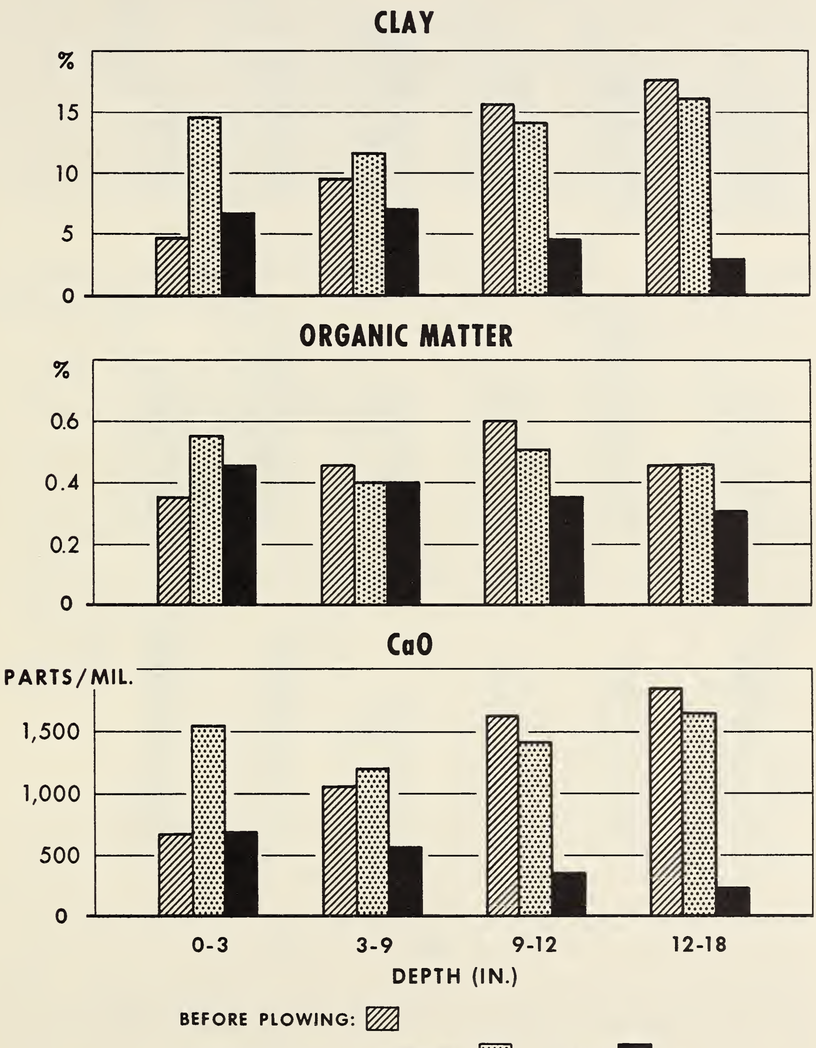

FIGURE 3.—Average soil conditions at various depths just before, just after, and 5 years after deep plowing on Amarillo loamy fine sand in Brownfield, Tex. Plowing averaged 15½ inches deep.

surrounding areas. Wind erosion completely nullified the effects of deep plowing and left the soil with much less clay and more sand than before deep plowing. Removal of clay was less severe in nonplowed fields, because there was little clay left to remove. No other factor than wind erosion conceivably could have buried or removed so much clay from the plowed plots. Other studies (*3*, *10*) have indicated that wind can sort out and remove silt, clay, and organic matter from the surface soil as no other factor can in a few years.

Potential annual soil loss by wind 5 years after plowing was very high for the top 4 inches of soil and moderate for that below 4 inches, as shown in table 1. The percentage of clods that may be brought up from below 4 inches, as by emergency tillage, was not sufficient to control wind erosion. Sand, such as this, without vegetative cover needs at least 85 percent of clods greater than 0.84 mm. to reduce the potential annual soil loss to an insignificant quantity of 5 tons per acre. This percentage of clods is unattainable on sand; therefore, this soil must be protected by vegetation or vegetative residue practically all the time.

TABLE 1.—*Soil cloddiness and potential annual soil loss by wind on two plots of Amarillo loamy fine sand 5 years after deep plowing at Brownfield, Tex.*

Plot and depth of soil sample [1] (inches)	Clods greater than 0.84 mm.	Potential annual soil loss by wind	Erosion
	Percent	*Tons per acre*	
Plot 1:			
0–1	19.0	490	Very high.
1–4	33.7	390	Do.
4–18	59.5	160	Moderate.
Plot 2:			
0–1	17.8	500	Very high.
1–4	55.6	220	High.
4–18	69.3	75	Moderate.

[1] Plot 1 was plowed 17 inches deep and plot 2, 14 inches.

Kansas

Changes in soil conditions of plowed and nonplowed fields in southwestern Kansas with years after plowing are given in figures 4–6.

Deep plowing increased substantially the percentage of nonerodible soil clods greater than 0.84 mm. in diameter in the top 4 inches of soil, hereafter called surface soil (fig. 4). One-half year after plowing, the surface soil on plowed land averaged about twice as high a percentage of clods as the surface soil of the nonplowed land. This difference diminished rapidly for about 2 years and less rapidly until the end of the 6½-year period, when the deep-plowed land averaged 32 percent of nonerodible clods and the nonplowed 27 percent in the surface soil. The difference in cloddiness for six pairs of comparable fields at the end of this period was statistically significant at the 20-percent level. Greater confidence no doubt would have resulted had

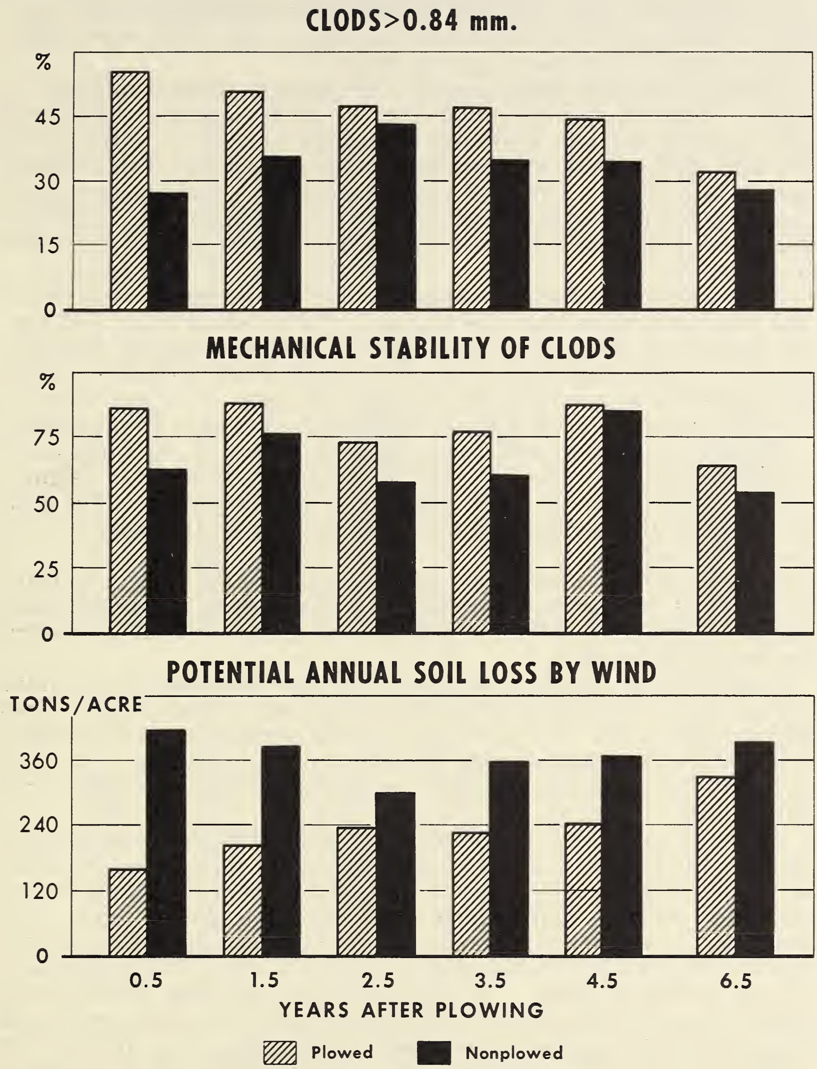

FIGURE 4.—Soil conditions in top 4 inches of plowed and nonplowed fields at indicated years after deep plowing in southwestern Kansas.

more than six pairs of fields been available for statistical comparison.

Deep plowing increased the mechanical stability of clods in the surface soil. Mechanical stability expresses resistance of clods to breakdown by mechanical forces such as tillage or abrasion by wind-blown soil grains. The greatest differences in mechanical stability between plowed and nonplowed fields existed immediately after plowing. Differences after 6½ years for comparable fields were statistically significant at the 20-percent level.

Deep plowing decreased greatly the potential annual soil loss by wind. This loss was computed from the percentage and stability of soil clods for climatic conditions of Garden City, Kans., during 1954 through 1956, with no crop residues on the surface and with a smooth soil surface (*5*, *7*). One-half year after plowing, this loss on plowed land was less than half of that on nonplowed land, but this difference decreased with years after plowing and almost disappeared at the end of 6½ years.

Deep plowing increased substantially the percentage of water-stable soil particles greater than 0.84 mm. and of those smaller than 0.02 mm. in diameter in the surface soil (fig. 5). Both of these soil fractions tend to increase about equally the percentage of nonerodible soil clods and decrease the potential soil loss by wind (*6*). The percentage of these fractions in the surface soil diminished with years after plowing.

Deep plowing decreased the proportion of sand in the surface soil on an average from 86 to 72 percent and increased the clay (significantly at the 5-percent level) from about 5 to 12 percent. The sand and clay in the surface soil remained practically the same for 6½ years after plowing.

Deep plowing increased the organic matter of the surface soil significantly at the 5-percent level (fig. 6). The organic matter remained significantly higher in the plowed than the nonplowed fields through the 6½-year period.

Deep plowing slightly decreased available phosphorus (P_2O_5) in the surface soil. This detrimental effect lasted only a year or two. Two and one-half years after plowing, available phosphorus in the surface soil was about the same on deep-plowed as nonplowed fields.

Deep plowing had no great or consistent effect on the pH of the surface soil.

As shown in figure 7, the percentages of nonerodible clods, mechanical stability of clods, clay, and organic matter at various depths before and after deep plowing indicate that plowing 20 inches deep with a disk plow tended to mix rather than invert the plowed layer. For example, the average clay content of the fields before plowing in this particular investigation was about 7 percent at the surface and 20 percent at a 20-inch depth. If the layer were completely inverted, the fields plowed 20 inches deep would have 20 percent at the surface and 7 percent at the furrow bottom, but due to mixing they had only 16 percent at the surface and 12 percent at the furrow bottom. Even with complete inversion, the clay brought up from a 20-inch depth on predominant types of sandy soil in this area would seldom be more than 20 percent as determined by the method of Bouyoucos (*1*).

Deep plowing increased the yield of sorghum grain, but apparently only for a limited period of years, as shown in table 2. The greatest average increase of 19.2 bushels per acre was obtained in 1958, which

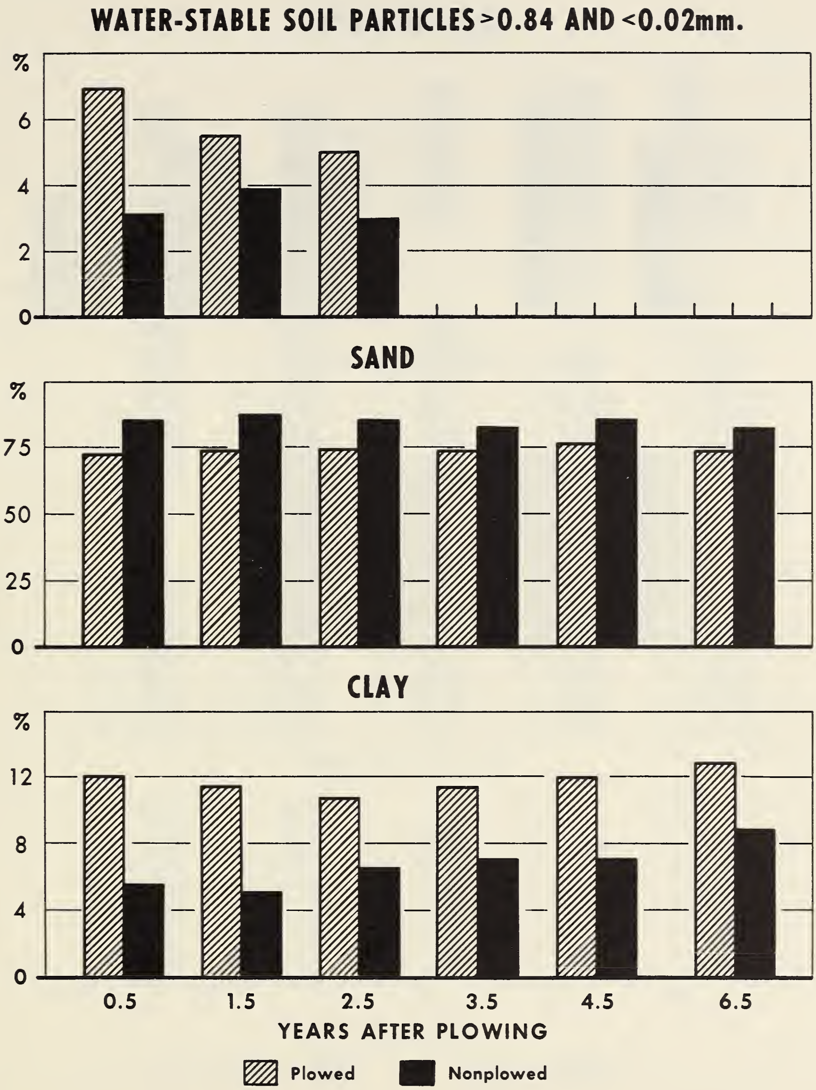

FIGURE 5.—Soil conditions in top 4 inches of plowed and nonplowed fields at indicated years after deep plowing in southwestern Kansas.

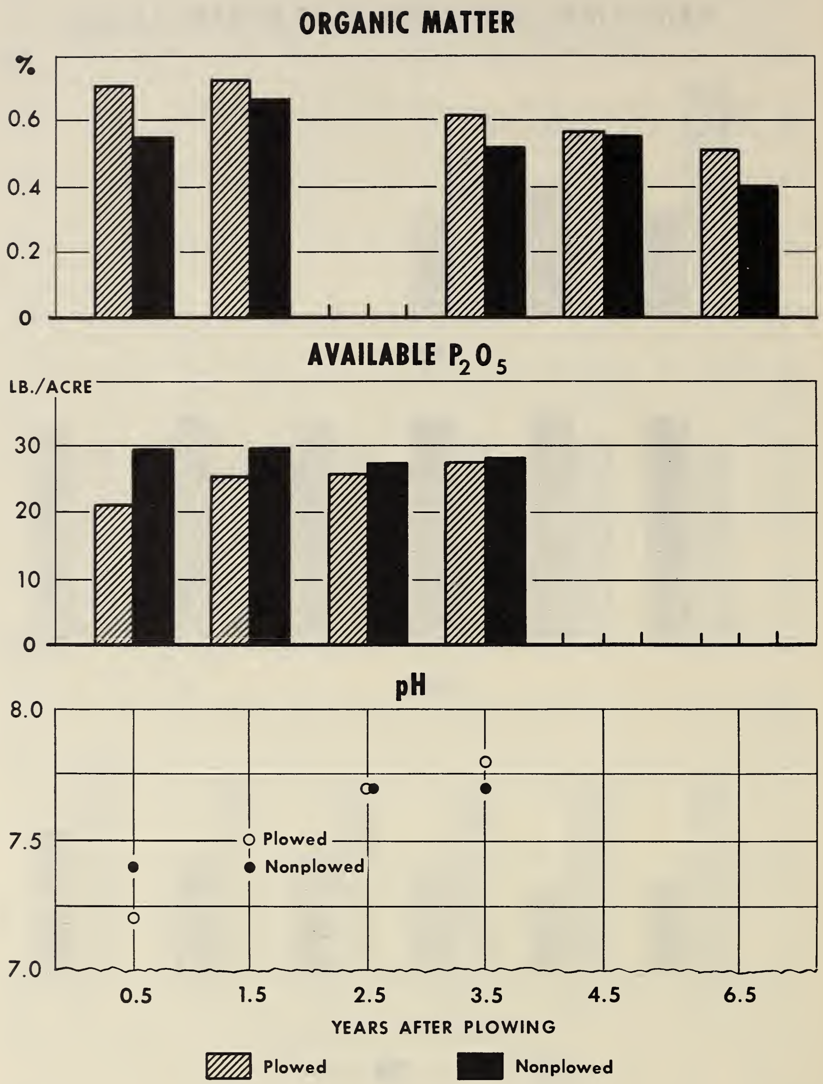

FIGURE 6.—Soil conditions in top 4 inches of plowed and nonplowed fields at indicated years after deep plowing in southwestern Kansas.

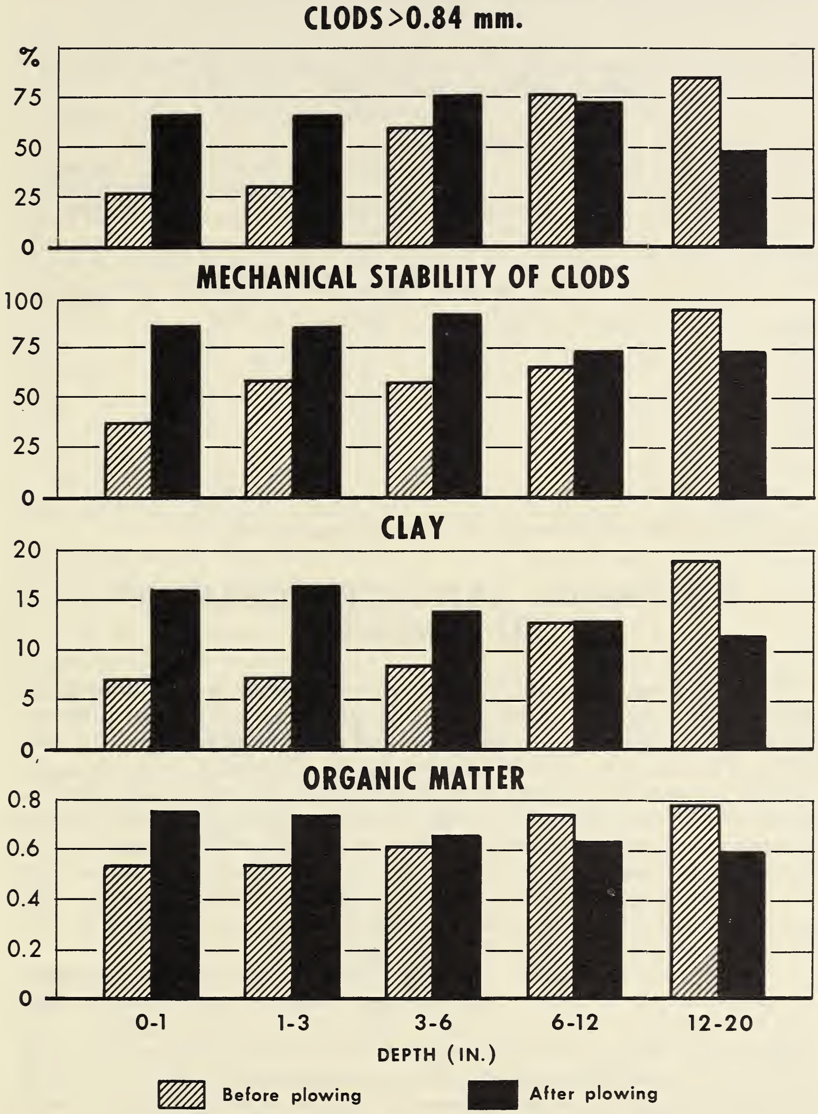

FIGURE 7.—Average soil conditions at various depths just before and just after deep plowing on Dalhart fine sandy loam and Dalhart and Vona loamy fine sands in southwestern Kansas. Plowing was 20 inches deep.

was a relatively wet year, and the smallest increase of 0.7 bushel per acre was in 1960, which was moderately favorable for sorghum yield. Apparently an increase in fertility brought about by the plowing almost disappeared before the end of the 6½-year period.

TABLE 2.—*Average yields of sorghum grain on plowed and nonplowed fields in southwestern Kansas* [1]

Year	Fields plowed in— Current year [2]	Fields plowed in— Previous years [2]	Nonplowed fields	Average increase due to plowing
	Bushels per acre	*Bushels per acre*	*Bushels per acre*	*Bushels per acre*
1954	32. 4*	39. 7**	27. 9	8. 0
1955	37. 4**	34. 1*	28. 4	7. 4
1956	14. 9*	4. 0	4. 7	4. 7
1957		20. 0*	15. 9	4. 1
1958		56. 9**	37. 7	19. 2
1960		34. 9	34. 2	. 7

[1] Based on three to six each of plowed and nonplowed fields.
[2] *=significant at 5-percent level and **=significant at 1-percent level, both based on yield difference between plowed and nonplowed fields.

DISCUSSION AND INTERPRETATION OF RESULTS

The data from Brownfield, Tex., were collected from 4-acre plots. Considerable amounts of sand from neighboring nonplowed plots accumulated on the deep-plowed plots and drastically changed the condition of the surface soil within a few years. Repeated listing brought some clay from lower depths, but continued wind erosion tended to remove the clay and leave the sand. The same changes would tend to take place in large blocks of land but less rapidly than in small plots, because the transported sand could not cover a block of land one-half to 1 mile wide as rapidly as it could a plot only 175 feet wide. The end results would be the same for both, but the time required for the end results would be greater for the large blocks.

In southwestern Kansas, plowing about 20 inches deep changed the soil in the top 4 inches on an average from a sand to a loamy sand or a loamy sand to a sandy loam. None of the plowed fields in this study had in the top 4 inches a soil texture any finer than a sandy clay loam; some were loamy sand and most were sandy loam. Generally plowing reduced the potential annual soil loss by wind, but the surface soil of plowed fields was still considerably wind erodible. Six and one-half years after plowing, the surface soil of plowed land on an average was a sandy loam and had 32 percent of nonerodible clods. The surface soil of the nonplowed land was a loamy sand and had 27 percent of clods.

Therefore, according to Chepil (*7*) and Chepil and Woodruff (*8*), the plowed fields needed on an average about 1,500 pounds and the

nonplowed 2,200 pounds per acre of standing sorghum stubble to keep the potential annual soil loss down to an insignificant quantity of 5 tons per acre, if we assume that the plowed and nonplowed fields had an average sandy loam and loamy sand, respectively. If the stubble were flattened, the deep-plowed fields would need 3,000 pounds and the nonplowed 4,400 pounds per acre to reduce the potential annual soil loss to an insignificant amount. Such quantities of stubble cannot be produced in dry years, and therefore serious wind erosion may be expected to occur even on deep-plowed fields.

Little soil was moved by the wind in southwestern Kansas during 1954 through 1960 and therefore little change in the texture and other characteristics of the soil has taken place. In the two deep-plowed plots in Texas, wind erosion was very serious; consequently, great changes in the texture and other characteristics of the soil occurred and more than nullified the initially favorable effects of deep plowing. Because the surface soil 5 years after plowing had on an average only 19 percent of nonerodible clods, it needed about 3,300 pounds per acre of standing sorghum stubble 12 inches high to reduce the potential annual soil loss to an insignificant quantity of 5 tons per acre. It would need about 6,600 pounds per acre of flattened sorghum stubble. That much stubble seldom can be grown under dryland conditions in that area. This means that where wind erosion is expected to be serious, deep plowing cannot be more than a temporary soil-improvement measure.

The more clay the soil contains, up to about 27 percent, the cloddier and consequently the more resistant it is to wind erosion (*5*). Resistance drops when clay exceeds 27 percent. However, deep plowing generally increased the clay in the surface soil from below 10 percent to only 10–20 percent. Nevertheless it did markedly reduce, at least temporarily, the susceptibility of sandy soil to wind erosion. The serious problem is to protect deep-plowed land from wind erosion.

SUMMARY AND CONCLUSIONS

Deep plowing of some types of sandy soil increased the organic matter, nitrogen, potassium (as K_2O), and calcium (as CaO) in the surface soil and therefore increased crop yields. All or some of these soil constituents apparently become depleted rather rapidly, because substantial yield increases lasted only a limited number of years.

Deep plowing increased the clay in the surface soil on an average from about 5 to 12 percent in 2 plots in Texas and 29 fields in Kansas. However, about 27 percent of clay in the surface soil is required for maximum benefit to control wind erosion.

In Texas within 5 years after plowing, severe erosion on 4-acre plots decreased the clay and consequently increased the sand content in the surface soil almost to before-plowing proportions. It also decreased the fertility elements to nearly before-plowing proportions. The 4 inches of surface soil had a high to very high susceptibility to erosion 5 years after deep plowing. It was concluded that severe wind erosion during the 5-year period largely nullified the favorable effects of deep plowing.

In Kansas deep plowing brought soil clods to the surface and therefore greatly reduced the susceptibility of the soil to wind erosion. The initially high cloddiness in the surface soil deteriorated within a

year or two and reached a level dependent on the proportion of clay brought to the surface. The more clay brought up, the more clods the surface soil contained. The clay remained in the surface soil as long as little or no wind erosion occurred, but it was rapidly depleted when wind erosion was severe.

Deep plowing of some sandy soil produces several beneficial results, but it must be considered only as an aid in wind-erosion control. In the areas studied, deep plowing alone cannot control wind erosion. It must be supplemented with other suitable erosion-control practices. If wind erosion is not controlled, beneficial results will be only temporary.

It is concluded from this study that effective measures to control wind erosion must be adopted if favorable results from deep plowing are to be maintained.

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